MACGILLIVRAY FREEMAN'S

DREAM BIG

ENGINEERING OUR WORLD

GRADE 1:

DAYLIGHT IN A BOTTLE

Grade level: 1

Lesson length: Lesson length: 2.5 hours (can be broken into smaller chunks)

Engineers are constantly looking for ways to bring natural daylight into buildings. It saves power and fuel for everyone. This concept is called “daylighting.” Students will experiment with radiant energy and the concept of refraction to develop a lighting system made out of recycled materials. Water bottle-based systems like the ones students create in this activity are in use in several impoverished areas.

In the Film

In *Dream Big*, we see ways that engineers are bringing light to the interior of buildings without the need for electricity. In the Transbay Transit Center, engineers have designed a way to bring natural sunlight into the station in order to make it more energy efficient. During this design challenge, students experiment with ways to make similar devices to light the homes of those in need.

NGSS Disciplinary Core Ideas

1-PS4.B Electromagnetic Radiation

Objects can be seen if light is available to illuminate them or if they give off their own light.

NGSS Engineering Practices

1-LS1-1 Crosscutting Concepts Influence of Engineering, Technology, and Science on Society and the Natural World

Every human-made product is designed by applying some knowledge of the natural world and is built by using materials derived from the natural world.

Key Words/Vocabulary

Daylighting: The idea of using skylights, mirrors, or other devices to bring natural daylight into a building.

Illumination: Lighting or light. The light that comes into a room, or that shines on something.

Opacity: Not allowing light to pass through. If something has a high degree of opacity, no light can get through. If it has a low degree of opacity, a lot of light can get through.

Opaque: A material that light is not able to pass through. Roofs and walls made of wood or stone are opaque.

Refraction: The bending of light as it passes through one material into another. Light bends a little when it moves from the air into water, for example.

Translucent: A material that light is partially able to pass through. Ice is translucent; so is frosted glass.

Transparent: A material that light is fully able to pass through. A window is transparent.

Materials

Per class:

- ☐ Making the Testing Box instructions
- ☐ Testing box:
  - ☐ Large cardboard box
  - ☐ Box cutter
  - ☐ Piece of black cloth or felt large enough to drape over a child's head
  - ☐ Duct tape
  - ☐ 3 images
- ☐ Means of darkening the classroom
- ☐ Computer and projector for showing a YouTube video

Per student:

- ☐ Light in a Bottle Testing Sheet
- ☐ Pencil

Per pair:

- ☐ 1 empty .5L water bottle, with cap
- ☐ 1 empty .5L water bottle, with cap, painted on the outside
- ☐ 1 empty .5L water bottle, with cap, with a line marked around the middle
- ☐ Simple black-and-white picture that students can use during testing of the light
- ☐ Flashlight
- ☐ Water
- ☐ Vegetable or olive oil
- ☐ Food coloring
- ☐ Funnel

Teacher Prep Notes

Before beginning this lesson, collect empty water bottles. For the research component of the activity, each pair of students will need one empty .5L water bottle and one empty water bottle that has been painted on the outside.

For the construction component of the activity, each pair will need an empty .5L water bottle marked with a black permanent marker line around the middle. The line is to indicate how far you will place the bottle into the box.

Prior to introducing the challenge to students, build the testing box using the Making the Testing Box instructions.

Be prepared to explain the vocabulary terms in this lesson. Be able to relate these terms to the students' experiments with different substances in water bottles and the way those substances affect how they see a picture.

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - **a.** How do you think people used to light their houses before electricity was invented?
   - **b.** Why do you think natural sunlight might be better than electricity for lighting a house during the daytime?
   - **c.** If you didn't have electricity to light up your home, what would you do?
   - **d.** Why do you think some people don't have electricity to light their homes?
2. Debrief as a whole class after viewing the film. Encourage students to reflect on the guiding questions you gave them.
3. Introduce the design challenge. Explain that today, students will be engineers who figure out a way to bring sunlight into a room without using electricity, and by using recycled materials.

Research and Gather Information:

60 minutes

1. Make the classroom as dark as possible (turn off lights, and draw shades or close blinds if possible). Ask students how well they can see. Open the shades but keep the electric lights off. Is it any better? Are there any places in the room where it's too hard to read or work? Elicit responses to what they would do if they had to get dressed, eat, or work in a dim or dark room, and then explain that this is exactly what many children and families who can't afford electricity have to do every day in countries all around the world. Today, they will try to come up with a way to make life better for people in this situation by making a room light without electricity.

2. Show the following video: https://youtu.be/hPXjzsXJ1Y0. It shows how simple plastic "light bottles" are acting as valuable indoor lamps for people who don't have access to electricity in urban slums. Ask students to explain, as best they can, how these interior lights are made. Tell students that during this engineering challenge, they will explore how to make the best "Light in a Bottle" using materials available at school.

3. Divide students into pairs. Give each pair a .5L water bottle, a black-and-white picture of something very simple, and a flashlight. Tell students to prop the picture up against some books or a wall. Distribute the Light in a Bottle Testing Sheet to each student, along with a pencil. Make sure the students understand what they are supposed to write or draw on this testing sheet. You might write down words that they could use in their descriptions, such as *wavy*, *blurry*, *fuzzy*, and *clear*.

4. Instruct students to experiment with how light travels through their soda bottle (filled only with the air inside) by turning on the flashlight and shining it through the bottle toward the picture. Ask students to describe what the black-and-white image looks like as it is illuminated through the water bottle. Ensure that students understand the term *illuminated* as you use it in context.

5. Afterward, have the students fill the water bottles with water. Have them repeat the procedure, shining the light through the bottle and recording what they see of the black-and-white image.

6. Have students repeat the procedure three more times, once with a half-filled bottle of vegetable oil, once with a half-filled bottle of water with one drop of food coloring, and once with a bottle half filled with water and five drops of food coloring. Note: Depending on your students, you can choose to have them pour the new test material into the bottles, or you can have prefilled bottles available. Each time, have students use their testing sheet to record how the different substances affect the illumination of the black-and-white image. Finally, have students repeat the experiment using the bottles that have been painted on the outside. They should write down their findings for this step as well.

7. Talk about the terms *translucent*, *transparent*, and *opaque*. Ensure understanding by asking students to use these terms as they describe their findings. Talk about the concept of refraction and how that relates to the water bottles full of air, water, and oil. Explain that refraction is the principle behind why they were able to move light to the image in different ways.

Plan a Solution: 30 minutes

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two key fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge.

Instruct each pair to draw a plan for what they think is the best combination and amount of materials (water, oil, paint, and food coloring) for their bottle, to make it light up a room by making use of sunlight. This plan should reflect the work conducted during the research stage and should demonstrate their understanding of light and refraction.

Make It: 15 minutes

Once students have drawn their plan, tell them to assemble the best version of their daylighting device. Visit each group and review how their experiences with the flashlight shaped their overall design and plan. If students are making obvious mistakes, allow them to continue and learn from those mistakes. Avoid offering solutions and instead encourage students to develop a secondary plan that demonstrates the evolution of their ideas and experiences.

Test: 20 minutes

Using the cardboard box you assembled beforehand, place student daylighting devices in the top hole, one at a time. Allow the students to look through the viewing hole into the box. You can either shine a flashlight onto the daylighting device while inside the classroom or take it outside to test with the sun!

Evaluate: 10 minutes

Allow students to think about and discuss the following questions:

1. Does your daylighting device illuminate the interior images of the box?
2. How does your daylighting device compare to the ones created by other teams?
3. How would you make it work better?

Taking It Further

Using littleBits electronics, develop a light meter that can be used by the students to gauge the success of their daylighting device, or use a Vernier Probe Light Sensor to measure their device's output.

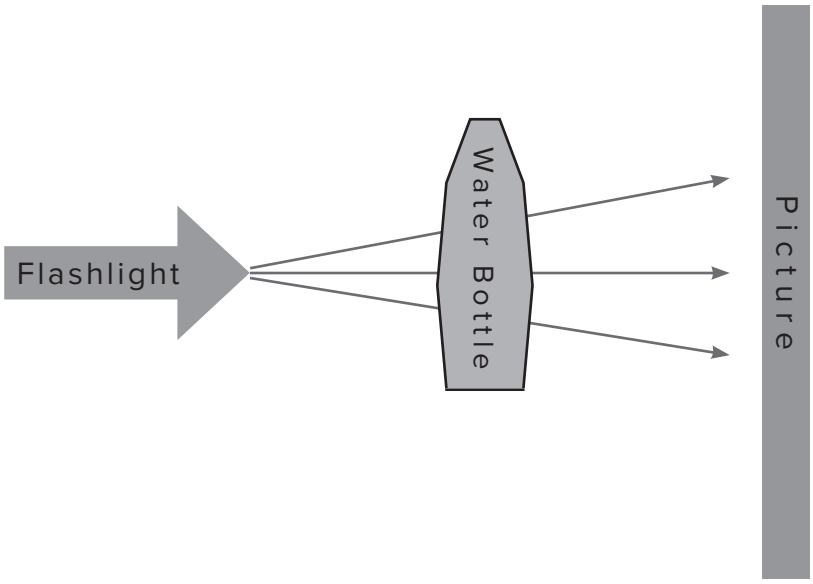
Engineers are exploring how to make current lightbulbs more efficient. Compare the new technologies that are in development to light our future: LEDs, MIT's incandescent bulbs, and lasers.

Explore the Liter of Light Project deeper through the following link to the My Shelter Foundation—Global Lighting Project: sculptthefuturefoundation.org/portfolio/my-shelter-foundation-global-lighting-project/.

Document your students' work through our social media outlet: #dreambigfilm

LIGHT IN A BOTTLE TESTING SHEET

Prop a picture up against some books or tape it to a wall. Place a water bottle 6 inches in front of it. Turn off the light to the classroom and turn on a flashlight. Shine the flashlight through the water bottle and onto the picture and record what it looks like!



1. Empty bottle:

2. Full water:

3. Half full with oil:

4. Half full with water and 1 drop food coloring:

5. Half full with water and 5 drops food coloring:

6. Painted outside of bottle:

MAKING THE TESTING BOX

Instruction Set

Materials

- ☐ Cardboard box (the larger the better)
- ☐ Box cutter
- ☐ Black cloth or felt
- ☐ Duct tape

1. Print three images of your choice to tape on the inside of the testing box. Students will use these images to determine and describe the amount of light illuminating the interior of the box when they test their device. The images can be of anything as long as they have enough detail for students to describe when light hits them. Suggestions are your school's mascot, a picture of someone's room, and so forth. Tape one picture on each interior side of the box, leaving one side blank. On the exterior of the box, mark the sides that have pictures so that you know their placement later.
2. Seal the box openings with duct tape to create a light-tight box.
3. On the top of the box, cut a 2.5-inch diameter hole. (This is the standard diameter of most .5L water bottles. If you are using bottles with a different shape or size, measure their diameter and cut a hole slightly smaller than that diameter for the bottle to fit snugly into.)
4. On the side of the box that you did not mark as containing an internal image, cut a viewing rectangle that is 6 inches wide and 2 inches high. This viewing rectangle should be about 1 inch above the bottom of the box.
5. Measure and cut a piece of black cloth that is slightly larger than the side of the box with the viewing hole.
6. Tape the cloth to the side of the box so that students must place their heads beneath it to look through the viewing hole when the box is resting on a table.

DREAM BIG VIDEO SERIES

WATCH *LEAN AND GREEN: ENGINEERING ALTERNATIVE ENERGY*

Alternative energy sources are one method engineers are using to grapple with the supreme challenge of slowing or halting climate change. Tour Ivanpah in California, the world's largest solar thermal plant: it reduces CO_2 emissions by over 1,000 tons every day. Learn how engineers are generating power through other sources too, like wind and ocean waves. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.

MacGillivray Freeman

NCEES advancing licensure for engineers and surveyors

ASCE American Society of Civil Engineers

BECHTEL

MACGILLIVRAY FREEMAN'S DREAM BIG ENGINEERING OUR WORLD

GRADE 1:

CROSS-CURRICULAR SUPPLEMENT

In the *Dream Big* Daylight in a Bottle lesson, students experiment with bringing light to the interior of buildings without the need for electricity. The engineering challenge is to design a lighting system out of recycled materials that best transmits natural sunlight to illuminate an interior. Students have the opportunity to work with a real-world solution currently being implemented to light homes in impoverished communities.

The general topics covered include electromagnetic radiation, refraction, opacity, and the use of recycled materials.

This cross-curricular supplement contains a math activity, an English language arts activity, and some additional ideas in both subject areas for exploring the topics and concepts introduced in the Daylight in a Bottle lesson.

Grade 1 Math: Light Chart

Estimated class time: 15 minutes

Summary

In the *Dream Big* Daylight in a Bottle activity, students experiment with making a recycled water bottle capture daylight and transmit images as clearly as possible. This math activity gives them a chance to put the classroom results into categories and to make comparisons. Students explore answers to these questions:

- Which one of my light bottles made the clearest image inside the testing box?
- How do my results compare with the results of my classmates?

Learning Objectives

- Demonstrate the ability to organize, represent, and interpret data in three categories
- Compare and contrast data points across three categories
- Evaluate data across three categories to determine which bottle produces the clearest image when light shines through it

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Materials

Per class:

☐ Paper or board space for making a class chart

☐ Writing implements for class chart

☐ Daylight in a Bottle activity supplies

Per student:

☐ Paper cutout of a lightbulb

☐ Daylight in a Bottle activity supplies

Preparation

This activity requires completion of the Daylight in a Bottle Activity. Students will use the data collected from the activity to create their chart.

Instructions

1. In step 6 of the Daylight in a Bottle activity, student pairs test the quality of light as it passes through bottles half full of different substances and record their results on their testing sheets. Once they have completed all of their tests, give each pair the cutout of a lightbulb. Direct each group to read through the notes they took. Then tell them to place the lightbulb cutout next to the bottle that transmitted the clearest image.
2. On a large piece of chart paper or the board, create a chart with the following headings: Plain Water, 1 Drop Food Coloring, 5 Drops Food Coloring, and Oil.
3. Invite each pair to come to the board and place an x in the category that matches the one where they placed the lightbulb cutout.
4. Together, count the number of x's in each category and write down the total at the bottom of each column

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Evaluation

After the counting is completed, hold a class discussion around questions such as the following:

- Did most of the teams achieve the same results? Why or why not?
- Were there other categories we could have used to compare results? What would they be?
- What other substances would be worth testing to see if they create clear illumination?

Activity Extensions

- See if results are different if substances are tested in glass jars instead of plastic bottles.
- Create a bar graph displaying results from the classroom chart.
- Ask students to brainstorm reasons why they may have had different "best" outcomes. What might groups have done differently from each other? How could you fix those? Then have the students run each of the experiments again and compare their results from the first round to the second round.

Other Ideas for Math

Here are a few more ways to connect the Daylight in a Bottle lesson with your math curriculum.

- Have students practice measuring by placing different quantities of liquid in each container.
- Use different shaped containers to explore volume. Have students predict which containers hold more water and then measure the volumes to find the results.

Grade 1 English Language Arts: Sources of Light

Estimated class time: 30 minutes

Summary

In the *Dream Big* Daylight in a Bottle activity, students experimented with making a recycled water bottle capture daylight. In this activity, students become aware of the way light is written about in stories and whether the source of the light is natural or human-made. Students think about these questions:

- What kinds of light are written about in stories?
- Where do different kinds of light come from?

Learning Objectives

- Identify the sources of different types of light from clues in stories
- Describe the ways light is written about in stories
- Distinguish between human-made and natural forms of light

Materials

Per class:

- ☐ The read-aloud book *The House in the Night* by Susan Marie Swanson
- ☐ Chart paper, enough for every three or four students

Per student:

- ☐ Drawing supplies

Preparation

Set context for students by holding a brief class discussion about the Daylight in a Bottle activity. Ask them to remember why engineers are creating ways to capture light from the sun in order to illuminate people's homes. To check understanding, ask, "What are the lights in our classroom powered by?" Make sure students grasp that their school and homes are primarily lit using electricity to power lightbulbs, rather than by sunlight.

Tell students that light can be the subject of stories too—all kinds of light. Ask students to share the names of stories or books they know that talk about light. In this activity, they will try to figure out how many different kinds of light they can find in one story.

Instructions

1. Tell students that you are about to read a book called *The House in the Night* aloud to them. As you read, ask them to notice every time a kind of light is mentioned or shown in a picture.
2. Pause at each page spread to give students time to think about whether a source of light is written about or shown. For example, in the beginning of the story is a page with the text, "In the house burns a light." Students should note the word "light" in the text; they should also see the sun coming up in the picture as well as the light emanating from the windows of the house. Keep a cumulative list on the board.
3. After you read the story, ask the class to review with you all the different kinds of light that were in the story (sunlight, starlight, moonlight, as well as light from electricity).
4. Ask which of these kinds of light are made by people? Encourage students to think about how many sources of light occur naturally, even though people depend so much on light from electricity. Remind them of the engineers in *Dream Big* and the one in the video who was bringing sunlight to people who did not have any electricity.
5. Organize students into groups of three or four and give each group a sheet of chart paper. Distribute drawing supplies. Ask students to draw all the different sources of light that they can think of. Beyond the ones in the story, they might think of flashlights, fireflies, campfires, and lightning. Ask students to write an "N" next to any natural light source on their paper and a "P" next to any light source made by people.
6. Ask each group to take turns holding up their chart papers so that the rest of the class can see how many light sources they drew. Ask students to point to the light sources that are made by people and those made by nature.

Closure

Ask students to explain what “human-made” means to them. Do they think a campfire is made by people or nature? There may be some disagreement. Point out that it depends on how you think about the word “human-made.” How do students think engineers use that word? What about daylight in a bottle? Maybe something can be a little bit of both!

Encourage students to see that the question is not either/or, black and white.

Activity Extensions

- Read the story *The House in the Night* again, but this time focus on the words associated with light: burn, glow, shine.
- Ask students to think of some songs that are about light and sing them together. Options include “Twinkle, Twinkle, Little Star” and “This Little Light of Mine.”
- Tell students a simple version of the biography of Thomas Edison, inventor of the lightbulb.

Book Connections for English Language Arts

The following books relate to the Daylight in a Bottle activity and can be incorporated into your ELA curriculum.

Day Light, Night Light by Franklyn M. Branley

I See Myself by Vicki Cobb

On a Beam of Light by Jennifer Berne

The Storyteller’s Candle by Lucia Gonzalez

Burn by Darcy Pattison